

1 **Influence of a knee brace intervention on perceived pain and patellofemoral loading in**
2 **recreational athletes.**

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21

22 **Abstract**

23 **Background:** The current investigation aimed to investigate the effects of an intervention
24 using knee bracing on pain symptoms and patellofemoral loading in male and female
25 recreational athletes. **Methods:** Twenty participants (11 males & 9 females) with
26 patellofemoral pain were provided with a knee brace which they wore for a period of 2
27 weeks. Lower extremity kinematics and patellofemoral loading were obtained during three
28 sports specific tasks, jog, cut and single leg hop. In addition their self-reported knee pain
29 scores were examined using the Knee injury and Osteoarthritis Outcome Score. Data were
30 collected before and after wearing the knee brace for 2 weeks. **Findings:** Significant
31 reductions were found in the run and cut movements for peak patellofemoral force/ pressure
32 and in all movements for the peak knee abduction moment when wearing the brace.
33 Significant improvements were also shown for Knee injury and Osteoarthritis Outcome Score
34 subscales symptoms (pre: male= 70.27, female= 73.22 & post: male= 85.64, female= 82.44),
35 pain (pre: male= 72.36, female= 78.89 & post: male= 85.73, female= 84.20), sport (pre:
36 male= 60.18, female= 59.33 & post: male = 80.91, female= 79.11), function and daily living
37 (pre: male= 82.18, female= 86.00 & post: male= 88.91, female = 90.00) and quality of life
38 (pre: male= 51.27, female = 54.89 & post: male= 69.36, female= 66.89). **Interpretation:**
39 Male and female recreational athletes who suffer from patellofemoral pain can be advised to
40 utilize knee bracing as a conservative method to reduce pain symptoms.

41

42 **Introduction**

43 Patellofemoral pain is the most common knee pathology (Dixit et al., 2007), characterized by
44 retro-patellar pain mediated by prolonged sitting, stair climbing, and sports activities (Al-
45 Hakim et al., 2012; Petersen et al., 2014). In athletic populations patellofemoral pain

46 symptoms force many to limit or even end their participation in sports activities (Blond &
47 Hansen, 1998). Importantly it has been shown that between 71-91 % of those who present
48 with patellofemoral pain have ongoing symptoms up to 20 years following diagnosis (Nimon
49 et al., 1998). Furthermore, it has been suggested that patellofemoral pain may serve as a
50 precursor to the progression of osteoarthritic symptoms in later life (Crossley 2014; Thomas
51 et al., 2010). The prevalence of patellofemoral pain in athletic populations is considered to be
52 between 8-40 %, with a greater frequency in females (Robinson and Nee, 2007; Boling et al.,
53 2010). Although Selfe et al., (2016) found that in a patellofemoral subgroup with higher
54 levels of physical activity 54% were males.

55

56 One of the functions of the patella as the bodies largest sesamoid bone is to enhance the
57 effective moment arm of the quadriceps muscle group and reduce the mechanical effort
58 required to extend the knee joint (Tumia and Maffulli, 2002). The articular surface of the
59 patellofemoral joint is comprised of dense hyaline cartilage which is capable of bearing high,
60 compressive loads (Garth, 2001). Patellofemoral contact forces are enhanced with increasing
61 angles of knee flexion and can reach up to 8 B.W during sports tasks (Thomee et al., 1999).

62

63 Although the incidence of patellofemoral pain is high, the causative mechanisms which lead
64 to the initiation of symptoms are not well understood. Those with patellofemoral pain are
65 much more likely to be physically active than age-matched controls (Fulkerson, 2002). The
66 current consensus is that there are multiple causative factors and that patellofemoral pain is
67 the end result of numerous pathophysiological processes (Witvrouw et al., 2014).
68 Aetiological research investigating the causes of patellofemoral symptoms has cited both
69 extrinsic and intrinsic mechanisms as contributory factors. Extrinsic mechanisms consist of

70 overtraining, training errors and inferior athletic equipment (Tumia and Maffulli, 2002).
71 Intrinsic biomechanical mechanisms consist of knee joint laxity, lower extremity mal-
72 alignment and muscular imbalance (Tumia & Maffulli, 2002). In addition mechanical
73 overloading of the patellofemoral joint is considered to be a key risk factor for the initiation
74 of pain symptoms in athletes (LaBella, 2004; Ho et al., 2012). The knee abduction moment
75 has also been shown to correspond with increased load borne by the lateral facet of the
76 patellofemoral joint and thus also contribute to the aetiology of patellofemoral pain syndrome
77 (Miyazaki et al., 2002; Zhao et al., 2007; Sigward et al., 2012; Myer et al., 2015). Excessive
78 patellofemoral forces and knee abduction moments in conjunction with a high training
79 volume leads to the initiation of symptoms, by overloading the patellofemoral joint beyond
80 functional adaptive structural responses (LaBella, 2004; Dye, 2005; Ho et al., 2012).

81

82 Treatment options for patellofemoral pain typically include; exercise, patella taping, knee
83 bracing, foot orthoses and manual therapy (Bolgla & Boling, 2010). Knee braces are defined
84 as external, non-adhesive apparatus which attempt to alter the position of the patella (Paluska
85 & McKeag, 2000). Knee braces come in a range of different interventions which typically
86 include knee braces in a range of materials, sleeves and bandages (Bolgla & Boling, 2010).
87 These are considered a relatively inexpensive treatment modality that can be purchased
88 independently or prescribed by a therapist (Warden, 2008). Importantly the majority of knee
89 braces can be applied by the wearer without assistance from a healthcare professional
90 meaning that the user has more control over the management of their condition (Paluska &
91 McKeag, 2000). A well-fitting knee orthosis can be used during normal daily activities and
92 also during athletic pursuits (Warden 2008).

93

94 Although a substantial body of literature exists regarding the mechanical effects of knee
95 bracing, there is currently a paucity of research investigating the influence of knee bracing for
96 the treatment of symptoms in those with patellofemoral pain. Powers et al., (2004) showed
97 that knee bracing provided an immediate improvement of 54 % in knee pain symptoms which
98 were assessed using a 10 cm visual analog scale. Arazpour et al., (2014) demonstrated that a
99 6 week intervention produced a significant reduction in knee pain symptoms. Khadavi &
100 Fredericson (2015) showed that knee bracing produced significant reductions in the knee pain
101 parameters which were examined via the Knee injury and Osteoarthritis Outcome Score
102 (KOOS). Callaghan et al., (2015) found that knee bracing proved to be significantly better
103 than control for reducing symptoms after a 6 week intervention, in patients with
104 patellofemoral pain. Miller et al., (1997) however revealed that knee bracing produced only
105 very small non-significant improvements in patellofemoral pain symptoms. Yu et al., (2015)
106 similarly showed that neither tibiofemoral nor patellofemoral bracing provided any additional
107 benefits in comparison to a control group which received no bracing.

108

109 To date there has been no published work which has examined the efficacy and effectiveness
110 of knee bracing for the treatment of symptoms in recreational athletes with patellofemoral
111 pain during sporting activities. Selfe et al., (2016) identified that different subgroups exist
112 within the patellofemoral pain population and different treatments regimes may be more
113 effective for each of the different subgroups. Selfe et al., (2016) showed that the 'strong'
114 subgroup was characterized by higher levels of physical activity. Suggestions for the strong
115 more athletic subgroup included; proprioceptive training, taping and bracing although this has
116 yet to be fully explored. Therefore the aim of the current investigation was to investigate the
117 effects of an intervention using knee bracing on pain symptoms and patellofemoral loading in
118 male and female recreational athletes. Research of this nature may improve understanding of

119 conservative management of patellofemoral pain and also provide recreational athletes with
120 an alternative treatment. The current study tests the hypothesis that intervention using knee
121 bracing will improve pain symptoms and reduce patellofemoral loading in recreational
122 athletes with patellofemoral pain.

123

124 **Methods**

125 *Participants*

126 Twenty participants (11 male and 9 female) volunteered to take part in the current
127 investigation. Participants were included into the study only if they showed symptoms of
128 patellofemoral pain and no evidence of any other pathology. Patellofemoral pain diagnosis
129 was made as a function of the clinical presentation of symptoms in accordance with the
130 recommendations of Crossley et al., (2002). Participants were firstly required to exhibit
131 symptoms of patellofemoral pain with no evidence of any other condition. The inclusion
132 conditions were a) anterior knee pain resulting from two or more of the following; sustained
133 sitting, climbing stairs, squatting, running, kneeling, and hopping or jumping; b) initiation of
134 pain symptoms not caused by a specific painful incident; and c) manifestation of pain with
135 palpation of the patellar facets. Participants were excluded from the study if there was
136 evidence of any other knee pathology or had previously undergone surgery on the
137 patellofemoral joint. In addition participants who had exhibited symptoms for less than 3
138 months or were taking any anti-inflammatory/ corticosteroid medications were also excluded.
139 Finally participants who were aged 50 or above were excluded in order to reduce the
140 likelihood of pain being caused by degenerative joint disease. Written informed consent was
141 provided in accordance with the declaration of Helsinki. The procedure was approved by the

142 Universities Science, Technology, Engineering, Medicine and Health ethics committee, with
143 the reference STEMH 295.

144

145 *Knee brace*

146 A single knee brace was used in this study, (Trizone, DJO USA), which came in three
147 different sizes; small, medium and large to accommodate all participants (Figure 1).

148

149 **@@@ Figure 1 near here @@@**

150

151 *Procedure*

152 Participants were required to report to the laboratory on two occasions. On their initial visit to
153 the laboratory they were required to complete five repetitions of three sports specific
154 movements'; jog, cut and single leg hop. In addition to this the participants also completed
155 the KOOS questionnaire in order to assess self-reported knee pain. Once the biomechanical
156 and KOOS data were obtained, participants were then provided with a knee brace in their size
157 which they were asked to wear for all of their physical activities for 14 days. Participants
158 were instructed to maintain their habitual sport/exercise regime and also recorded the number
159 of hours spent exercising/ playing sport during the 14 days prior to the intervention and also
160 during the intervention itself. Following the 14 day intervention participants returned to the
161 laboratory where the protocol was repeated whilst wearing their knee brace.

162

163 Kinematic information from the lower extremity joints was obtained using an eight camera
164 motion capture system (Qualisys Medical AB, Goteburg, Sweden) using a capture frequency
165 of 250 Hz. Dynamic calibration of the system was performed before each data collection
166 session. Calibrations producing residuals <0.85 mm and points above 4000 in all cameras
167 were considered acceptable. To measure kinetic information an embedded piezoelectric force
168 platform (Kistler National Instruments, Switzerland Model 9281CA) operating at 1000 Hz
169 was utilized. The kinetic and kinematic information were synchronously obtained and
170 interfaced using Qualisys track manager.

171

172 To quantify lower extremity joint kinematics in all three planes of rotation the calibrated
173 anatomical systems technique was utilized (Cappozzo et al., 1995). Retroreflective markers
174 (19 mm) were positioned unilaterally allowing the; foot, shank and thigh to be defined. The
175 foot was defined via the 1st and 5th metatarsal heads, medial and lateral malleoli and tracked
176 using the calcaneus, 1st metatarsal and 5th metatarsal heads. The shank was defined via the
177 medial and lateral malleoli and medial and lateral femoral epicondyles and tracked using a
178 cluster positioned onto the shank. The thigh was defined via the medial and lateral femoral
179 epicondyles and the hip joint centre and tracked using a cluster positioned onto the thigh. To
180 define the pelvis additional markers were positioned onto the anterior (ASIS) and posterior
181 (PSIS) superior iliac spines and this segment was tracked using the same markers. The hip
182 joint centre was determined using a regression equation that uses the positions of the ASIS
183 markers (Sinclair et al., 2013). The centers of the ankle and knee joints were delineated as the
184 mid-point between the malleoli and femoral epicondyle markers (Sinclair et al., 2015;
185 Graydon et al., 2015). Each tracking cluster comprised four retroreflective markers mounted
186 onto a thin sheath of lightweight carbon-fibre. Static calibration trials were obtained allowing
187 for the anatomical markers to be referenced in relation to the tracking markers/ clusters. The

188 Z (transverse) axis was oriented vertically from the distal segment end to the proximal
189 segment end. The Y (coronal) axis was oriented in the segment from posterior to anterior.
190 Finally, the X (sagittal) axis orientation was determined using the right hand rule and was
191 oriented from medial to lateral. Data were collected during run, cut and hop movements
192 according to below:

193

194 *Run*

195 Participants ran at $4.0 \text{ m.s}^{-1} \pm 5\%$ and struck the force platform injured limb. The average
196 velocity of running was monitored using infra-red timing gates (SmartSpeed Ltd UK). The
197 stance phase of running was defined as the duration over $> 20 \text{ N}$ of vertical force was applied
198 to the force platform (Sinclair et al., 2013).

199

200 *Cut*

201 Participants completed 45° sideways cut movements using an approach velocity of 4.0 m.s^{-1}
202 $\pm 5\%$ striking the force platform with their injured limb. Cut angles were measured from the
203 centre of the force plate and the corresponding line of movement was delineated using
204 masking tape so that it was clearly evident to participants (Sinclair et al., 2015). The stance
205 phase of the cut-movement was similarly defined as the duration over $> 20 \text{ N}$ of vertical force
206 was applied to the force platform (Sinclair et al., 2013).

207

208 *Hop*

209 Participants began standing by on their injured limb; they were then requested to hop forward
210 maximally, landing on the force platform with same leg without losing balance. The arms
211 were held across the chest to remove arm-swing contribution. The hop movement was
212 defined as the duration from foot contact (defined as > 20 N of vertical force applied to the
213 force platform) to maximum knee flexion. The hop distance was recorded in the initial data
214 collection session as was maintained for the second testing session.

215

216 *Data processing*

217 Dynamic trials were processed using Qualisys Track Manager and then exported as C3D
218 files. GRF and marker data were filtered at 50 Hz and 15 Hz respectively using a low-pass
219 Butterworth 4th order filter and processed using Visual 3-D (C-Motion, Germantown, MD,
220 USA). Joint kinetics were computed using Newton-Euler inverse-dynamics, allowing net
221 knee joint moments to be calculated. Angular kinematics of the lower extremity joints were
222 calculated using an XYZ (sagittal, coronal and transverse) sequence of rotations. To quantify
223 joint moments segment mass, segment length, GRF and angular kinematics were utilized
224 using the procedure previously described by Sinclair, (2014). The net joint moments were
225 normalized by dividing by body mass (Nm/kg). Discrete lower extremity joint kinematic
226 measures were extracted for statistical analysis were 1) peak angle and 2) relative range of
227 motion (representing the angular displacement from footstrike to peak angle).

228

229 Knee loading was examined through extraction of peak knee abduction moments,
230 patellofemoral contact force (PTCF) and patellofemoral contact pressure (PTS). PTCF was
231 normalized by dividing the net PTCF by body weight (B.W). PTCF loading rate (B.W/s) was

232 calculated as a function of the change in PTCF from initial contact to peak force divided by
233 the time to peak force.

234

235 PTCF during running was estimated using knee flexion angle (kf) and knee extensor moment
236 (KEM) through the biomechanical model of Ho et al., (2012). This model has been utilized
237 previously to resolve differences in PTCF and PTS in different footwear (Bonacci et al.,
238 2013; Kulmala et al., 2013; Sinclair, 2014) and between those with and without
239 patellofemoral pain (Keino & Powers, 2002). The model has also been shown to be
240 sufficiently sensitive to detect differences in PTCF between sexes (Sinclair and Bottoms,
241 2015).

242

243 The effective moment arm distance (m) of the quadriceps muscle (QM) was calculated as a
244 function of kf using a non-linear equation, based on information presented by van Eijden et
245 al., (1986):

246

$$247 \quad \text{QM} = 0.00008 \text{ kf}^3 - 0.013 \text{ kf}^2 + 0.28 \text{ kf} + 0.046$$

248

249 The force (N) of the quadriceps (FQ) was calculated using the below formula:

250

$$\text{FQ} = \text{KEM} / \text{QM}$$

251

252 Net PTCF (N) was estimated using the FQ and a constant (C):

253

254

$$\text{PTCF} = \text{FQ} * C$$

255 C was described in relation to kf using a curve fitting technique based on the non-linear

256 equation described by van Eijden et al., (1986):

257

$$C = (0.462 + 0.00147 * kf^2 - 0.0000384 * kf^2) / (1 - 0.0162 * kf + 0.000155 * kf^2 - 0.000000698 * kf^3)$$

259

260

261 PTS (MPa) was calculated using the net PTCF divided by the patellofemoral contact area.

262 The contact area was described using the Ho et al., (2012) recommendations by fitting a 2nd

263 order polynomial curve to the data of Powers et al., (1998) showing patellofemoral contact

264 areas at varying levels of kf.

265

266

$$\text{PTS} = \text{PTCF} / \text{contact area}$$

267

268 *Statistical analyses*

269 Descriptive statistics of means and standard deviations were obtained for each outcome

270 measure. Shapiro-Wilk tests were used to screen the data for normality. Differences in

271 biomechanical and knee pain parameters were examined using 2 (BRACE) x 2 (GENDER)

272 mixed ANOVA's. Differences in physical activity duration prior to and during the

273 intervention were examined using a paired samples t-test. Statistical significance was

274 accepted at the $p < 0.05$ level (Sinclair et al., 2013). Effect sizes for all significant findings
275 were calculated using partial η^2 ($p\eta^2$). All statistical actions were conducted using SPSS
276 v22.0 (SPSS Inc, Chicago, USA). In accordance with the recommendations of Roose &
277 Lohmander, (2003) minimal perceptible clinical improvements (MCIP) were considered to be
278 10 points on each of the KOOS subsections.

279

280 **Results**

281 Tables 1-4 present the knee pain and patellofemoral variables obtained before and after the
282 knee brace intervention. The results show that both knee pain and patellofemoral loading
283 were significantly influenced by the intervention using knee bracing.

284

285 *Physical activity duration*

286 No significant differences ($P > 0.05$) in physical activity duration were observed, participants
287 completed mean 4.40 and SD 2.11 hours of physical activity/ sport prior to the intervention
288 and mean 4.37 and SD 2.32 during.

289

290 *Knee pain*

291 For the KOOS symptoms ($P < 0.05$, $p\eta^2 = 0.71$) and pain ($P < 0.05$, $p\eta^2 = 0.71$) subsections
292 significant improvements were observed following the intervention, with 16 of the 20
293 participants demonstrating improvements. For the KOOS function and daily living ($P < 0.05$,
294 $p\eta^2 = 0.65$) and sports ($P < 0.05$, $p\eta^2 = 0.66$) subsections significant improvements were found
295 following the intervention, with 17 and 18 of the 20 participants demonstrating improvements

296 respectively. Finally for the quality of life subsection a significant improvement ($P < 0.05$, η^2
297 = 0.28) was found as a function of the intervention, with 16 of the 20 participants
298 demonstrating improvements (Table 1).

299

300

@@@ Table 1 near here @@@

301

302 *Patellofemoral kinetics*

303 *Run*

304 For both PTCF ($P < 0.05$, $\eta^2 = 0.27$) and PTS ($P < 0.05$, $\eta^2 = 0.24$) there were significant
305 reductions following the intervention. For PTCF loading rate there was also a significant
306 ($P < 0.05$, $\eta^2 = 0.39$) reduction following the intervention. Finally, there was a significant
307 ($P < 0.05$, $\eta^2 = 0.25$) reduction in the peak knee abduction moment following the intervention
308 (Table 2).

309

@@@ Table 2 near here @@@

310

311 *Cut*

312 For both PTCF ($P < 0.05$, $\eta^2 = 0.29$) and PTS ($P < 0.05$, $\eta^2 = 0.25$) there were significant
313 reductions following the intervention. For PTCF loading rate there was also a significant
314 ($P < 0.05$, $\eta^2 = 0.30$) reduction following the intervention. Finally, there was a significant
315 ($P < 0.05$, $\eta^2 = 0.23$) reduction in the peak knee abduction moment following the intervention
316 (Table 3).

317 @@@ *Table 3 near here* @@@

318

319 *Hop*

320 There was a significant ($P < 0.05$, $\eta^2 = 0.27$) reduction in the peak knee abduction moment
321 following the intervention (Table 4).

322

323 @@@ *Table 4 near here* @@@

324

325 *Joint kinematics*

326 *Run*

327 For peak hip flexion there was a significant ($P < 0.05$, $\eta^2 = 0.34$) reduction following the
328 intervention. Similarly for peak knee flexion there was a significant ($P < 0.05$, $\eta^2 = 0.35$)
329 reduction following the intervention.

330

331 *Cut*

332 For peak hip flexion there was a significant ($P < 0.05$, $\eta^2 = 0.32$) reduction following the
333 intervention. Similarly for peak knee flexion there was a significant ($P < 0.05$, $\eta^2 = 0.34$)
334 reduction following the intervention.

335

336 *Hop*

337 For peak hip flexion there was a significant ($P < 0.05$, $p\eta^2 = 0.33$) reduction following the
338 intervention. Similarly for peak knee flexion there was a significant ($P < 0.05$, $p\eta^2 = 0.36$)
339 reduction following the intervention.

340

341 **Discussion**

342 The aim of the current investigation was to determine the biomechanical efficacy and clinical
343 effectiveness of knee bracing in recreational athletes with patellofemoral pain. To the authors
344 knowledge this represents the first investigation to examine the effects of knee bracing on
345 recreational athletic participants suffering from patellofemoral pain. Given the high incidence
346 of patellofemoral pain in recreational athletes, research of this nature may provide important
347 clinical information regarding the conservative management of patellofemoral pain.

348

349 The first key observation from the current work supports our hypothesis in that knee bracing
350 served to significantly reduce all of the participant reported indicators of knee pain. The
351 magnitude of the improvements in all subsection of the KOOS questionnaire exceeded the
352 minimum threshold required for clinical relevance (Roose & Lohmander, 2003). This in
353 conjunction with the observation that the majority of participants ($N = \geq 16/20$) exhibited
354 improvements in symptoms is a key clinical finding. Importantly, this work also showed that
355 activity duration did not differ, meaning that improvements in pain symptoms did not appear
356 to be mediated through reductions in physical activity. This indicates that knee bracing has
357 the potential to provide clinically meaningful improvements in patient reported symptoms in
358 recreational athletes with patellofemoral pain.

359

360 It is proposed that the improvements in patient reported symptoms were mediated through
361 reductions in PTCF and PTS which were observed following the brace intervention. This
362 observation is similarly in support of our hypothesis and it is proposed that it relates to the
363 reduction in the magnitude of peak knee flexion found in the brace condition. Reduced knee
364 flexion serves to attenuate the knee extensor moment requirement during landing tasks, thus
365 the loads imposed on the patellofemoral joint are reduced (Thomee et al., 1999). It is
366 unknown whether this observation relates to restriction about the knee joint imposed by the
367 brace which would be undesirable for athletes where full range of movement is required.
368 Future work should therefore focus on the proprioceptive and potential restrictive effects of
369 these braces.

370

371 In addition reduced knee abduction moments were also observed as a function of the brace
372 intervention. This finding may also have clinical relevance given the relation between knee
373 abduction moment and the aetiology of patellofemoral pain. As such reductions in the
374 magnitude of the knee abduction moment may be a further mechanism by which knee bracing
375 served to improve patellofemoral pain symptoms. Knee bracing aims to reduce the magnitude
376 of the abduction moment created by the ground reaction force by brace applying a constant
377 moment about the knee (Pagini et al., 2010). Therefore it is proposed that this finding relates
378 to the mechanical influence of the knee brace itself.

379

380 A potential drawback of the current investigation is that patellofemoral loading was
381 quantified using a musculoskeletal modelling approach. This technique was necessary as
382 direct quantification of patellofemoral forces necessitate the utilization invasive measurement
383 techniques, which are not possible due to ethical considerations. Regardless, the utilization of

384 the knee extensor moment as the primary input measurement into the calculation of
385 patellofemoral loading means that antagonist forces that act in the opposite direction of the
386 joint remain unaccounted for (Sinclair & Bottoms, 2015). Therefore this may lead to an
387 underestimation patellofemoral loading during the dynamic activities (Sinclair & Selfe,
388 2015). A further potential limitation of the current work is the lack of a control group. Whilst
389 the current study observed improvements in self-reported pain as a function of the
390 intervention despite no change in activity, the lack of a control group means the possibility
391 that improvements were caused by a factors other than those measured here cannot be ruled
392 out. Future clinical research may wish to investigate the effects of knee bracing in
393 patellofemoral pain in recreational athletes using a randomized controlled research design.

394

395 In conclusion, although previous analyses have investigated the effects of knee bracing, the
396 current knowledge with regards to the effects of bracing in recreational athletes with
397 patellofemoral pain is limited. Recreational athletes represent a significant proportion of
398 patellofemoral pain patients, thus research of this nature may provide important clinical
399 information. The current investigation therefore addresses this firstly by providing a
400 comparison of knee pain symptoms before and after an intervention using knee bracing and
401 secondly by contrasting the biomechanics of different sports movements before and after the
402 intervention. In addition this study shows significantly improvements in patient reported
403 symptoms and significantly reductions in knee loading following the intervention. The key
404 implication from this study is that male and female recreational athletes who suffer from
405 patellofemoral pain may be advised that utilizing knee bracing as a conservative management
406 can reduce pain symptoms.

407

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Table 1: Knee pain symptoms as a function of both knee brace intervention and gender.

	Male				Female			
	Brace		No-brace		Brace		No-brace	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
KOOS symptoms	70.27	9.49	85.64	9.81	73.22	10.53	82.44	11.30
KOOS pain	72.36	14.02	85.73	7.99	78.89	7.20	84.20	10.35
KOOS sport	60.18	17.84	80.91	17.59	59.33	9.85	79.11	14.00
KOOS function and daily living	82.18	8.96	88.91	12.09	86.00	5.68	90.00	7.16
KOOS quality of life	51.27	10.78	69.36	16.86	54.89	13.30	66.89	17.74

Table 2: Patellofemoral kinetics during running as a function of both knee brace intervention and gender.

	Male				Female			
	Brace		No-brace		Brace		No-brace	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
PTCF (B.W)	3.21	0.93	3.40	0.68	2.98	0.78	3.82	0.56
PTS (MPa)	10.11	2.07	10.87	2.74	9.41	2.00	11.60	1.62
PTCF loading rate (B.W/s)	40.19	12.76	45.16	9.35	35.37	13.53	47.09	14.02
Peak abduction moment (Nm/kg)	-0.89	0.30	-1.01	0.26	-0.86	0.21	-0.94	0.14

Table 3: Patellofemoral kinetics during cutting as a function of both knee brace intervention and gender.

	Male				Female			
	Brace		No-brace		Brace		No-brace	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
PTCF (B.W)	3.47	1.01	3.76	0.65	3.25	0.79	3.95	0.84
PTS (MPa)	10.75	2.21	11.52	2.13	10.10	2.11	11.70	2.47
PTCF loading rate (B.W/s)	42.04	15.50	39.07	6.54	34.23	10.69	42.17	15.50
Peak abduction moment (Nm/kg)	-0.61	0.29	-0.81	0.23	-0.86	0.31	-0.94	0.11

Table 4: Patellofemoral kinetics during the single leg hop as a function of both knee brace intervention and gender.

	Male				Female			
	Brace		No-brace		Brace		No-brace	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
PTCF (B.W)	3.32	0.99	3.56	0.52	3.10	0.66	3.56	0.48
PTS (MPa)	10.31	2.12	11.13	2.49	9.75	1.57	10.77	1.59
PTCF loading rate (B.W/s)	37.76	9.99	39.21	5.40	36.82	9.75	40.99	11.29
Peak abduction moment (Nm/kg)	-1.19	0.40	-1.40	0.32	-1.04	0.25	-1.14	0.33

Figure(s)
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